Pilot Scale Testing of Carbon Negative, Product Flexible Syngas Chemical Looping Gasification Process

Andrew Tong, Liang Zeng, Deepak Sridhar, Dawei Wang, Robert Statnick, and Liang-Shih Fan

WILLIAM G. LOWRIE DEPARTMENT OF CHEMICAL AND BIOMOLECULAR ENGINEERING
THE OHIO STATE UNIVERSITY

PROJECT OVERVIEW

The Syngas Chemical Looping (SCL) process developed at the Ohio State University (OSU) can efficiently convert coal and biomass into electricity, hydrogen, and/or liquid fuel with zero or negative net CO_2 emission. Independent process analyses indicate that SCL is a novel process that is 10+% more efficient the state-of-the-art processes. SCL has been successfully demonstrated at bench and sub-pilot scales. A 250 kW_{th} pilot scale SCL plant will be constructed and demonstrated under the ARPA-E project. The project will pave the way for further scale up and commercialization of this efficient, environmentally friendly technology.

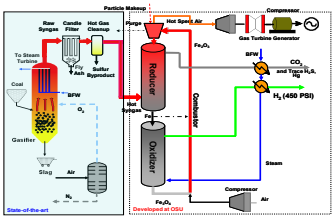
Reducer: $C_nH_{2n}O_n + Fe_2O_3 \rightarrow CO_2 + H_2O + Fe$

Oxidizer: $Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Combustion Train: $Fe_3O_4 + O_2 \rightarrow Fe_2O_3 + Heat$

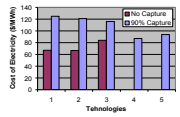
Overall reaction

$C_nH_{2n}O_n + H_2O/O_2 \rightarrow CO_2 + H_2/Heat$



Techno-Economic Evaluation of SCL

	IGCC Process	SCL Process Electricity	Conventional Coal to Hydrogen Process	SCL Process
Coal feed(ton/hr)	132.9	132.9	132.9	132.9
Carbon Capture(%)	90	100	90	100
Hydrogen(ton/hr)	0	0	14.4	15.6
Net Power(MW)	348.1	422.0	57.6	57.4
Efficiency(%HHV)	34.8	42.2	62.7	66.5



Technologies
1. Sub-Critical PC;
2. Supercritical PC;
3. IGCC;
4. SCL-USC;
5. SCL – H_2 – CC

Project Impacts

- GHG Emission Reduction *(Carbon Negative)*
- Energy Security Enhancement *(Oil Displacement)*
- Energy Efficiency Improvement *(10+% Efficiency Enhancement)*
- Technological Leadership Restoration *(Advanced Chemical Looping)*
- Quick implementation and job creation *(Strong Partnership)*

OXYGEN CARRIER DEVELOPMENT

Desired Properties

- Good oxygen carrying capacity
- Good gas conversions in both the reduction and oxidation reactions
- High rates of reaction
- Satisfactory long term recyclability and durability
- Good Mechanical Strength
- Suitable heat capacity and high melting points
- Low cost and ease in scale up of synthesis procedure
- Resistance to contaminant and inhibition of carbon formations
- Health and Environmental Impacts

Possible Oxygen Carrier Candidates

- Nickel Oxide
- Copper Oxide
- Iron Oxide
- Cobalt Oxide

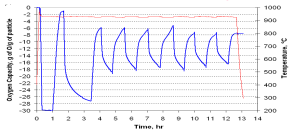
Comparisons of the Key Properties of Different Metal Oxide Candidates

	Fe_2O_3	NiO	CuO	CoO
Cost	+	–	–	–
Oxygen Capacity (wt %)	30	21	20	21
Thermodynamics	+	+	+	+
Kinetics/Reactivity	–	+	+	–
Melting Points	+	~	–	+
Strength	+	–	~	~
Environmental& Health	~	–	~	–

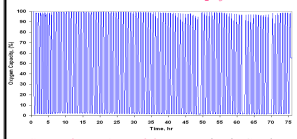
+: positive; –: negative; ~neutral

TGA RESULTS

Recyclability of Commercial Fe_2O_3



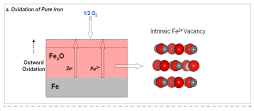
Recyclability of Composite Fe_2O_3 Particles



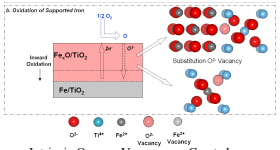
Composite Fe_2O_3 Particles can Maintain Good Reactivity in Multiple Cycles

SIMULATION STUDIES

Pure Fe_2O_3: Fe Cations Diffuse via Intrinsic Fe^{x+} Vacancy

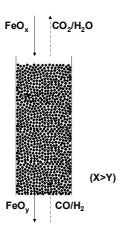


Composite Fe_2O_3: O^{2-} Anions Diffuse via O^{2-} Vacancy

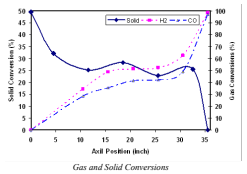


Intrinsic Oxygen Vacancy are Created Enhanced Ionic Conductivity

BENCH SCALE TESTING



Gas-Solid Countercurrent Flow Pattern



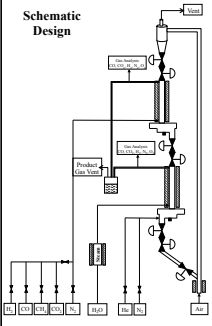
Gas and Solid Conversions

> 100 hours operational experience

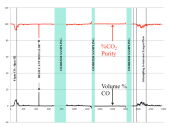
- > 99% syngas conversion and H_2 purity
- ~50% iron oxide conversion

SUB-PILOT TESTING

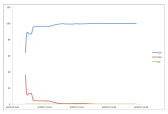
Schematic Design



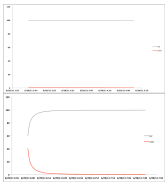
Reducer Profile - Syngas



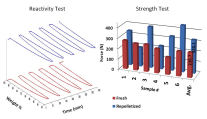
Reducer Profile - Methane



Oxidizer Profile

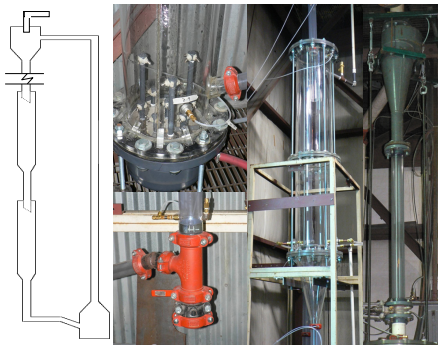


Post-Experiment Solids Analysis



- > 250 hours continuous operations at reactive conditions
- 3 day campaign result shows consistently high syngas conversion and hydrogen purity
- > 99% syngas conversion and H_2 purity
- Particle reactivity and strength maintained

SCL PILOT SCALE COLD MODEL STUDIES

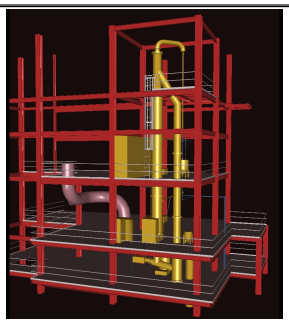


Objective: Construct and Validate 1:1 Pilot Scale Cold Model SCL Unit Operation

Summary:

- Reactor fabrication and assembly completed
- Over 20 solids/gas flow operating conditions successfully tested
  - System operation is robust
- >100 hrs continuous operation
- Nonmechanical system design successfully demonstrated
- Operational experience gained was used in developing the P&ID and operating procedures of SCL pilot scale unit at high temperature and pressure

250 kW_{th} PILOT SCALE PROCESS



Summary

1. Cold Model Studies Completed
2. Front End Engineering and Design (FEED) completed
3. Preliminary unit design and HAZOP review performed
4. Functional Specifications Documents generated
5. P&ID Competed
6. Finalizing Collaborative Testing Agreement between parties
7. Construction to be completed in 2012
8. Operation starting in late 2012

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- To be demonstrated with National Carbon Capture Center